

PIEZOELECTRIC

— Longitudinal Mode

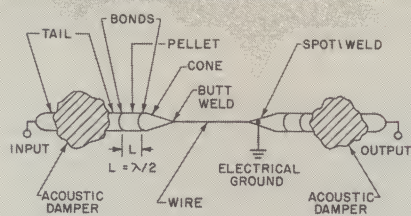


Fig. 3

Essentially the same as magnetostrictive. Exception: polarized piezoelectric pellet is bonded directly into the line. Provides higher delay-bandwidth products, less attenuation and has greater vibration and shock compatibility.

The principle of the piezoelectric delay line basically is the same as the magnetostrictive except that the sonic wave is generated by a polarized pellet bonded directly into the line. The progression of the wave down the line is similar to the longitudinal mode magnetostrictive delay line. Unlike the magnetostrictive transducer, the piezoelectric transducer is primarily a voltage sensitive device whose impedance is capacitive. The transducer's coupling efficiency is substantially greater than the magnetostrictive type, providing lower insertion losses and consequent reductions in the amount of associated amplifying circuitry required. Another feature is the very large dynamic range of input signal levels which the delay line can accommodate, typically 50 to 60 db, compared with approximately 20 db for the magnetostrictive delay line.

The piezoelectric transducer provides a more rigid device able to withstand up to 30 G's, 20-2,000 cps and continue to operate efficiently.

PIEZOELECTRIC

Longitudinal

Maximum Frequency	1.2 Mc (RZ) 2.4 Mc (NRZ)
Maximum Delay	40 M sec
Minimum Delay	5 μ sec
Signal-to-Noise Ratio	
Static (single pulse) max.	30:1
Dynamic (signal pattern) max.	10:1
Insertion Loss:	
Transducer Losses (each transducer)	10-15 db.
Losses in Delay	
Medium	1-2 db/M sec
Support Losses	Dependent on delay line geometry.
Delay Tolerance @ 25°C (fixed outputs & fixed taps)	±0.04 μ sec
Taps Available	No
Characteristic Impedance (Frequency Dependent)	1-10K ohms
Temperature Coefficient of Delay (min.)	1-2 ppm/°C
Dynamic Range of Input	60 db.
Vibration (Operating)	30 G's (20-2000 cps)
Shock (Operating)	50 G's (11 M sec)
Temperature Operating Range (max.)	-55 to +100C

PIEZOELECTRIC

— Direct Torsional Mode

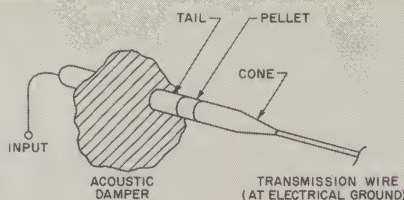


Fig. 4

Similar to magnetostrictive. Main advantage, in addition to 40% less wire, is that this type is almost totally insensitive to noise introduced by shock and vibration. Higher frequencies make it useful for a variety of commercial and military applications.

Unlike the magnetostrictive torsional mode delay lines, this new piezoelectric direct torsional delay line requires no mode converter. It is similar to the piezoelectric longitudinal in that a polarized pellet is bonded directly into the wire. However, a torsional polarized pellet is used instead of a longitudinal. When a voltage is applied to the pellet, it actually twists to generate the torsional wave. An output can be obtained by using a similar transducer. As with the longitudinal mode of the piezoelectric technique, the torsional mode obtains higher frequency resolution, since it is not subject to fringing effects. This capability for high frequency operation increases permissible data storage on a given delay line, and combines with outstanding vibration and shock compatibility to provide a device ideally suited for many military applications. It also lends itself to denser packaging.

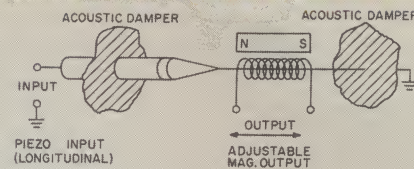
PIEZOELECTRIC

Direct Torsional

Maximum Frequency	2.5 Mc (RZ) 5.0 Mc (NRZ)
Maximum Delay	40 M sec
Minimum Delay	5 μ sec
Signal-to-Noise Ratio	
Static (single pulse) max.	30:1
Dynamic (signal pattern) max.	10:1
Insertion Loss:	
Transducer Losses (each transducer)	10-15 db.
Losses in Delay	
Medium	1-2 db/M sec
Support Losses	Dependent on delay line geometry.
Delay Tolerance @ 25°C (fixed outputs & fixed taps)	±0.04 μ sec
Taps Available	No
Characteristic Impedance (Frequency Dependent)	1-10K ohms
Temperature Coefficient of Delay (min.)	1-2 ppm/°C
Dynamic Range of Input	50 db.
Vibration (Operating)	30 G's (20-2000 cps)
Shock (Operating)	200 G's (11 M sec)
Temperature Operating Range (max.)	-55 to +100C

COMBINED

Piezoelectric/Magnetostrictive



(INPUT = 20 μf) (OUTPUT = 100 μh)
HYBRID DELAY LINE
Fig. 5

For adjustable output transducers, retaining some of the advantages of the piezoelectric design.

In applications where the fixed delay time of the piezoelectric delay line cannot be accepted, delay lines employing a piezoelectric input transducer and an adjustable magnetostrictive output transducer can be furnished. Electrical and mechanical performance of these combination types can be expected to fall between the pure magnetostrictive and piezoelectric designs.

INPUT-OUTPUT CIRCUITRY DESIGN SERVICE

Complete memory packages, consisting of wire sonic delay line and all circuitry in encapsulated or printed wiring form, are available.

This service has been created for the ease of design and use of complete memory systems.

The extensive experience possessed by G.E. in the design and manufacture of wire sonic delay lines enables optimum performance of the complete package.

COMBINED

(Piezoelectric Input) (Magnetostrictive Output)

Maximum Frequency	1.2 Mc (RZ) 2.4 Mc (NRZ)
Maximum Delay	40 M sec
Minimum Delay	5 μ sec
Signal-to-Noise Ratio	
Static (single pulse) max.	30:1
Dynamic (signal pattern) max.	10:1
Insertion Loss:	
Transducer Losses (each transducer)	See appropriate type
Losses in Delay	
Medium	1-2 db/M sec
Support Losses	Dependent on delay line geometry.
Delay Tolerance @ 25°C (fixed outputs & fixed taps)	±0.1 μ sec
Taps Available	Yes
Characteristic Impedance (Frequency Dependent)	1-10K ohms in 200-1500 ohms out
Temperature Coefficient of Delay (min.)	1-2 ppm/°C
Dynamic Range of Input	50 db.
Vibration (Operating)	20 G's (20-2000 cps)
Shock (Operating)	100 G's (11 M sec)
Temperature Operating Range (max.)	-55 to +100C

Recording Techniques and Application Information

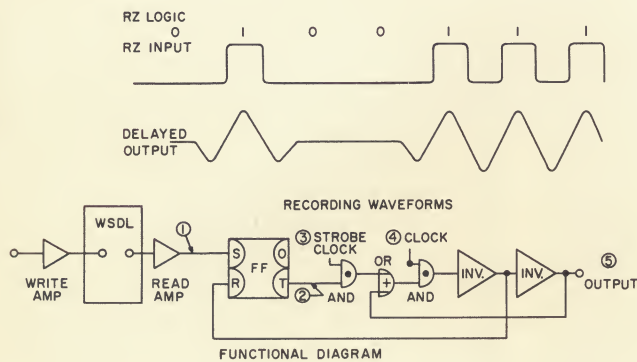


Fig. 6

RETURN TO ZERO (RZ) RECORDING

This is the simplest modulation mode. A digit ONE is represented by the presence of a pulse, a digit ZERO by its absence. In this form of recording, only one threshold detection level is necessary. This simplifies the circuitry and the timing tolerances. It is also possible to peak detect and avoid some of the "jitter" problems associated with amplitude variations. It is less sensitive to timing tolerances, and requires comparatively simple associated circuitry. It makes use of only $\frac{1}{2}$ the maximum theoretical information rate and storage capacity of a given delay line. It is useful for low-to-medium capacity for digital storage.

TIMING TOLERANCES

Typical timing tolerance for a 1 mc RZ recording is:

Total available time: 1/PRR	1.00 μ s
Strobe pulse (loop response)	0.20 μ s
Vibration & Shock Jitter	0.10 μ s
Random Pulse Jitter	0.05 μ s
Delay Drift	0.55 μ s
Clocking	0.05 μ s
Delay Adjustment	0.05 μ s
TOTAL	1.00 μs

Note: Without peak detection the random jitter may go as high as 0.15 μ s cutting the allowable delay drift to 0.45 μ s.

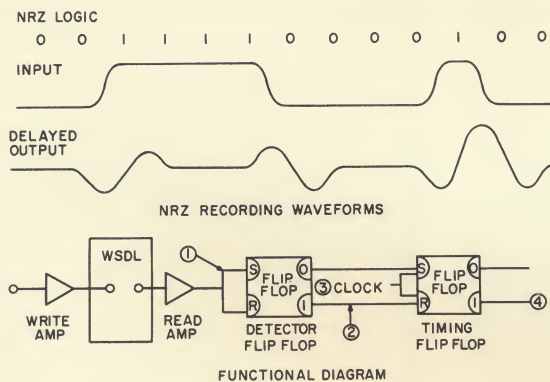


Fig. 7

NON-RETURN TO ZERO (NRZ) RECORDING

Amplitude levels instead of pulses are used in this mode to represent binary ONES and ZEROS. The NRZ modulation offers maximum storage capacity for a given delay line. For a given amount of storage, only one-half the access time is required. The information storage is twice that of the RZ or Bipolar techniques. However, with NRZ modulation there is some increase in circuit complexity. This mode is more sensitive to noise and the environmental effects of shock, vibration and temperature. Because both the turn-on and turn-off driving waveforms to the delay line must be identical, usually more read voltage amplification is required than either BZ and Bipolar for the same efficiency. The NRZ is well suited for larger capacity delay lines and high speed operation.

TIMING TOLERANCES

Typical timing tolerances for a 2 mc NRZ delay line are:

Total allowable tolerance	0.50 μ s
1/PRR	0.50 μ s
Random word jitter (max.)	0.15 μ s
Temperature drift (max.)	0.10 μ s
Vibration jitter (max.)	0.05 μ s
Delay Setting tolerance (max.)	0.05 μ s
Flip Flop response (max.)	0.15 μ s
TOTAL	0.50 μs

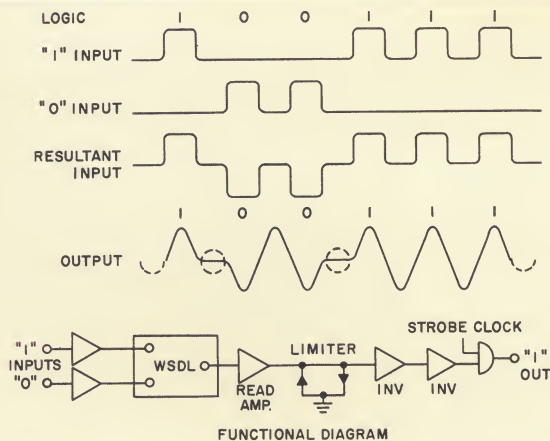


Fig. 8

BIPOLAR RECORDING TECHNIQUE

A third and more sophisticated recording technique is possible. This technique, Bipolar, is intended to suppress noise by having a signal always present. This continual signal is possible by employing a push-pull form of RZ recording in which both ONES and ZEROS are written onto the line, but in opposite polarities. As in RZ, this modulation uses only $\frac{1}{2}$ the maximum storage capacity of the delay line. Because an information pulse is present at all times, the noise immunity is high and greater effective signal amplitude for a given voltage supply is present. Circuitry is more complex and usually power dissipation is higher than in RZ. This type of modulation is particularly well suited where reliable performance under adverse conditions is required, as in military or other severe applications.

TIMING TOLERANCES

Typical timing tolerance for BiPolar Recording @ 1 mc:

Total available tolerance 1/2PRR	0.50 μ s
Strobe	0.10 μ s
Vibration Jitter	0.10 μ s
Random Pulse Jitter	0.10 μ s
Delay Drift	0.10 μ s
Clocking	0.05 μ s
Adjustment of Delay	0.05 μ s
TOTAL	0.50 μs

CARRIER TYPE DELAY LINES

Although this bulletin discusses primarily the digital applications of wire sonic delay lines, their most frequent use today, they can readily accept carrier type information such as would be used in communications, radar, or sonar equipment. The delay line can perform a vital function in these equip-